RF AND SRF COMPONENTS FOR B*ERL*INPRO*

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Abstract

The Energy Recovery Linac (ERL) project B*ERL*inPro is funded as of January 2011 and is now in the design phase. B*ERL*inPro should demonstrate the feasibility to use ERL technology for next generation light sources and other ERL applications. The planned SRF layout is described including the RF transmitter, the couplers and the configuration of the SRF modules. The project has been reviewed by a machine advisory committee (MAC).

INTRODUCTION

In the search for the next generation light source, the ERL (energy recovery linac) principle seems to be a promising candidate. The characteristic parameters for such a light source will be a beam current of 100 mA or more, an emittance of 1 mm mrad and bunch length in the ps-range or in special modes even in the 100 fs-range. The ERL principle has been demonstrated [1][2][3], but the high current and low emittance in combination has not been shown yet. To demonstrate that an ERL-based accelerator can achieve these parameters, the B*ERL*inPro project has been approved by the Helmholtz-Gemeinschaft and the BMBF and will be built at the HZB.

BASIC LAYOUT OF BERLINPRO

The layout of B*ERL*inPro is shown in Figure 1. There will be a superconducting (sc) 1.3 GHz photo-injector cavity that delivers an energy gain of 1.5-2 MeV. The booster section consists of three-two cell cavities which envisioned to accelerate the beam up to an energy of 6.5 MeV. Both sections form the injector. The merger magnets connect the injector to the recirculating ERL ring. To minimize costs, the main linac consists only of three seven-cell strongly higher order mode (HOM) damped cavities. The energy of B*ERL*inPro is not a critical parameter that has to be demonstrated. It is rather the emittance and the beam current. In the future more cavities may be added in the opposing straight section or the building needs to be expanded. The main parameters of B*ERL*inPro are listed in Table 1. Due to the fact that B*ERL*inPro is a development project and costs have to be minimized, there are some reduced parameters (e.g. transmitter power) in the start phase with room for subsequent upgrades given in brackets.

Table 1: Basic Parameters of B*ERL*inPro

Energy	~ 50 MeV
Merger energy	~ 6.5 MeV
Beam current	100 mA
Emittance	1 mm mrad (normalized)
Electron source	superconducting RF photoinjector
Gun transmitter	270 kW 1.3 GHz
Booster cavities	3 x 2-cell
Booster transmitter	2 x 200 (270) kW + 1x 15 (200) kW
Linac cavities	3 x 7 cell
Linac transmitter	3 x 15 kW

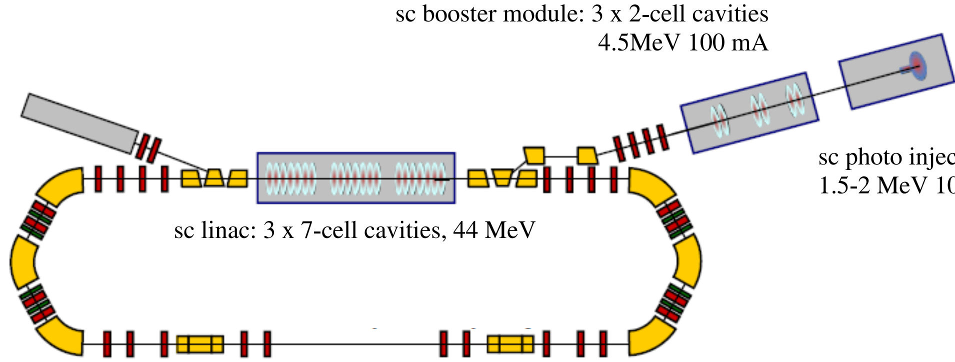

Figure 1: Layout of *BERL*inPro

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RF SYSTEMS FOR INJECTOR

The injector linac of B*ERL*inPro consists of a superconducting RF photo gun module and a booster module with three two cell cavities. Due to the fact that there is no energy recovery in the injector path, the full beam loading power has to be provided by the RF system. That results in a power level of 650 kW for a 100 mA 6.5 MeV beam! In addition there are waveguide and circulator losses estimated at 20-30% (length dependent). This shows the need for high power couplers at the cavity and high power RF transmitters.

Cavity for the superconducting RF photo-injector

A new type of superconducting RF photo injector will be developed in the framework of B*ERL*inPro [4]. The design will be follow experience gained with the Rossendorf SRF gun [5]. The cavity will be (n+1/2) cell with a frequency of 1.3 GHz including a normal-conducting photocathode with high quantum efficiency. To achieve high brightness and short pulses, the exit energy of the gun cavity has to be 1.5-2 MeV.

There will be three development steps for the gun system. A first cavity is running at currents below 1µA with a superconducting Pb cathode film [6] leaving issues concerning beam loading and average power requirements to a later stage of the project. This gun cavity is developed in collaboration with Jefferson Lab, DESY, MBI, HZB and the A. Soltan Institute with the primary goal to demonstrate beam dynamics aspects of high brightness electron pulses. The second cavity, including a complex cathode/cavity interface, is under development and expected to deliver a few mA current while the cavity for the production gun has to reach the 100 mA current goal.

Fundamental power couplers for the injector cavities

The beam loading of the electron source is the driver to use high power couplers. The needed energy gain of 1.5-2 MeV and the beam current of 100 mA results in a beam loading power of 150-200 kW.

To reduce the coupler kicks two couplers should be used giving a minimum power level of 100 kW per fundamental power coupler. At the cERL project [2] a 1.3 GHz scaled version of the KEKB 508 MHz coupler [7] has been developed. It is in the conditioning phase [8]. Figure 2 show two couplers on the coupler test stand.

A power level of 200 kW travelling wave is expected. Results achieved so far are 50 kW_{CW} and more than 100 kW in long pulse mode.

The couplers have a fixed coupling value. It is planned to use pairs of these couplers at each cavity in the injector linac of B*ERL*inPro.

Figure 2: cERL couplers on the coupler test stand

Booster module

The booster module for B*ERL*inPro will be based on the design of the Cornell module [9], that consists of five 2-cell cavities and was already successfully tested with beam [10]. This module is based on two cell cavities with beam pipe ferrite HOM dampers. Due to the fact, that the Cornell couplers will not reach the required power level for the gun cavity, it is planned to replace them with the cERL couplers and increase the RF power level. Because of the higher power at the cavities, the number of cavities may be reduced to three in case of B*ERL*inPro. The detailed drawings for the modified module are in development.

Transmitters for the injector

At the HZB a high stability transmitter for IOT or klystron use has been developed [11]. It can be adapted to different power levels by changing the power supply parameters. Two transmitters have been realized, a 16 kW 1.3 GHz IOT transmitter in use at the HoBiCaT test facility [12] and an 80 kW 500 MHz IOT transmitter shown in Figure 3 at the Metrology Light Source (MLS) [13].

The gun and booster transmitter will be based on this transmitter using a 270 kW 1.3 GHz klystron. The call for tender is out and the order of the transmitters will follow this year. The transmitters must generate 270 kW (linear range of the klystron) to supply at least 200 kW to the cavity taking into account the losses in the (cooled) WR650 waveguides and the circulator.

Even though three booster cavities will be installed, there will be only two 200 kW and one 15 kW transmitter in the first stage of B*ERL*inPro. This is due to cost restrictions. The power of the 200 kW transmitters can be increased to 270 kW or the 15 kW transmitter replaced by a 200 kW one in an upgrade for acceleration of up to 100 mA.

A field gradient of ~10 MV/m is needed to provide an energy gain of 4.5 MV in two cavities. For a machine study mode (10 MeV at the merger with reduced current), a field gradient of ~17.5 MeV/m is necessary in two cavities. The third cavity will be equipped with a 15 kW

Figure 3: The 80 kW IOT based transmitter used at the MLS. This transmitter is used as prototype for the klystron-based 270 kW transmitters for the injector cavites at B*ERL*inPro.

solid state transmitter that will serve as a prototype for the main linac cavities. It can be used to chirp the beam.

RF SYSTEMS FOR MAIN LINAC

In the main Linac the beam will be recirculated, that means, the effective beam loading is low resulting in only medium power requirements for transmitters and couplers. On the other hand the beam passes twice and the beam current in the cavities is doubled. Possible upgrades for a second turn will result in 400 mA in the cavities.

Cavities for the Linac

The Linac cavities are under development in cooperation with Technical University Dortmund, University Rostock, JLab and Cornell University. It is planned to develop strongly HOM damped 7-cell cavities using JLab-type waveguide dampers [14]. Due to cost restrictions only three cavities will be installed at B*ERL*inPro. A field gradient of 18 MV/m is needed to achieve an energy of 50 MeV at B*ERL*inPro. It is under evaluation, if a coaxial fundamental power coupler [15] or a waveguide coupler will be used.

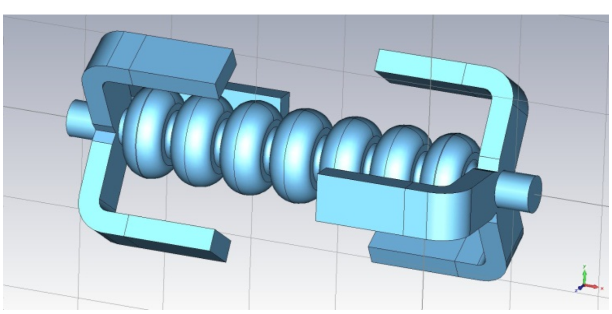

Figure 4: First outline of a 7-cell cavity with waveguide HOM dampers (courtesy B. Riemann)

Transmitters for the Linac

The beam loading power at the linac cavities is in the order of 1 kW or less. The power level of the Linac transmitters is dominated by the power needed to handle the microphonic detuning. A few kW of power need to be installed, hence solid-state amplifier based transmitters are probably the best solution. There are several commercial transmitters on the market. A power level of 15 kW is planned. However, since prices continue to drop, the order for the transmitters will be placed at the latest point possible in the project schedule (except for one prototype). The prototype will be procured in 2012 and tested at the HoBiCaT facility. The RF transmission line will be realized by a 3-inch coaxial cable.

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